Starting with 35 grams of ethyl aminoacetate we recovered practically one-half of the aminoacid ester in the form of its hydrochloride, and obtained 19 grams of the isothiocyanacetate. This reaction is being investigated further and will be applied for the preparation of other new types of polyketide mustard oils. If this method of synthesis finds as wide an application as we anticipate, it will enable us to obtain several isothiocyanates of new types, which should be of great biochemical interest.

[1] Johnson and Hemingway, *J. Amer. Chem. Soc., Easton, Pa.*, **38**, 1916 (1550).
[2] Fischer, E., *Berlin, Ber. D. Chem. Ges.*, **34**, 1901 (441).
[3] Andreasch, *Wien, Monatshefte Chem.*, **27**, 1906 (1211).

THE GEOLOGY OF THE FIJI ISLANDS

By Wilbur G. Foye

DEPARTMENT OF GEOLOGY, MIDDLEBURY COLLEGE, MIDDLEBURY, VERMONT

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The period between July, 1915 and March, 1916 I spent as a Sheldon Travelling Fellow of Harvard University, in a study of the geology of the Fiji Islands. Special attention was given to the structure and relations of the elevated limestones. Of the larger islands, Viti Levu, Vanua Levu, Taviuni, Kandavu, Mbengha, and Ovalau were visited. Three islands of the Yasawa group and eighteen of the Lau group were likewise studied. The following paper records the principal facts concerning the geology of the major divisions of the group.

1. Viti Levu.—Viti Levu is the southern of the two larger islands of Fiji. It is 94 miles long from east to west and 55 miles broad. The southeastern side of the island and a large portion of the eastern and northeastern sides are low delta flats overgrown with mangrove bushes. The flats merge into a young, narrow coastal plain which extends 5 to 10 miles inland, where it meets an uplifted coastal plain of soft marls, now carved into mature hills, 70 to 100 feet in height. The older plain slopes gradually upward for 5 or 6 miles from its edge, until it rests unconformably on the interior, volcanic hills at heights of 600 to 700 feet. Elsewhere the volcanic hills approach the shore and form the coastline for the greater part of the circumference of the island.

The whole interior of the island is characterized by maturely dissected insequent hills, though quite extensive flats are sometimes found near the rivers. The rocks forming the interior hills are frequently sandstones and marls in contrast to the volcanic rocks of the coast. The western and northern shores of the island are very irregular. Drowned valleys abound and many are so filled with delta deposits that

even small boats find difficulty in entering the river-mouths through the tangle of mangrove bushes.

The geological history of the island is more complex than has been previously stated.[1] From a hasty survey of the interior of the island I inferred that an old land of slates and red sandstones was intruded by a batholithic mass which solidified as gabbro, diorite and granite. The mountain block thus formed was deeply eroded and the igneous rocks were exposed. Volcanoes then burst forth and a series of andesitic and rhyolitic flows were poured out over the eroded surface.

The aggrading flows were later deeply eroded and submerged. A coraliferous conglomerate was laid down on the submerged surface and, during a period of oscillatory movements, several hundred feet of marl and claystones with occasional thin seams of coal were deposited. This period was followed by one of more decided submergence, during which approximately 150 feet of coraliferous limestones was laid down. The entire series will be spoken of, for reasons which will appear in the following paragraph, as the 'folded sediments.'

Compressive stresses were then developed in this portion of the earth's crust. The limestones and older rocks were uplifted and sharply folded along lines running in general N. N. W. by S. S. E. The folding was so intense that the limestones were occasionally transformed to marble. A period of faulting and volcanism followed during which the island assumed somewhat of its present form, and a series of volcanic hills were built up near the coast. Erosion and submergence then allowed marls and interbedded coraliferous limestones to be laid down uncomformably as a thin veneer about the edge of the island. These sediments will be spoken of as the 'coastal series.'

Again the island was differentially uplifted. The wide lagoon extending northwest toward the Yasawa islands was initiated by tilting in that direction and, at the same time, the coastal plain at the eastern side of the island was elevated. During the latter part of the epoch, volcanic rocks were injected into the coastal series and the Yasawa islands were built up. Recent differential movements have uplifted the southwestern shore of Viti Levu and at the same time depressed the Yasawa islands. In general the present coral reefs are developing on platforms which originated during the deposition of the coastal series.

2. *Vanua Levu.*—Vanua Levu, the northern of the two larger islands of Fiji, is 104 miles long from east to west and 20 to 25 miles in width. The eastern portion of the island is split by a long, narrow bay extending inland from northeast to southwest for 50 miles. To the eastern peninsula, thus formed, are appended several peninsulas which jut

out to the eastward. The whole circumference of the inland is marked by pocket harbors and jutting headlands.

Along the southern and eastern sides of the island a rough country of volcanic hills extends 6 or 8 miles inland. The principal divides are found in these hills. The larger rivers run north and northwest across elevated plains 200 to 300 feet high before forming flood-plains along the northern coast.

The geological history of the island is not so complex as that of Viti Levu. The fundamental rocks of the island are not exposed, to the writer's knowledge. Their character is, therefore, problematic. Into these rocks were intruded batholithic masses which solidified to form gabbro. The old land was then greatly eroded and the plutonic rocks were exposed. Later the island subsided. During the erosion and subsidence volcanic intrusions mantled the irregular land surface unconformably with a cover of acid andesites and rhyolites.

The island remained submerged throughout the period of sedimentation and folding in which the folded sediments of Viti Levu were developed. Submarine volcanoes were active and 2000 to 3000 feet of ash and agglomerate, largely composed of hypersthene andesite, were conformably laid down on the submerged surface. At the time of the uplift of the coastal series of Vitu Levu, Vanua Levu was elevated into an island form, The movements were accompanied by faulting and tilting and have continued to the present.

The period of uplift has been complicated by downward movements from time to time which may best be studied near Lambasa on the northern coast. During a still-stand a local peneplain was developed far into the interior which now is found at an elevation of 50 to 200 feet. The island was later uplifted and the peneplain just described was carved into sub-mature hills near the coast. A period of submergence followed during which coraliferous limestones were deposited about the spur-ends of the coastal hills. The region was then elevated and the limestones are now found from 50 to 100 feet above the sea. A recent submergence has allowed volcanic silts, brought down by the rivers, to fill up valleys eroded in the limestone. Since the uplift a series of basaltic eruptions have scattered their debris over the surface of the island but at a period so remote that the basaltic cones are now eroded to sub-maturity.

Elevated coral reefs are known from but one place along the northern coast. They occur at an elevation of 75 feet, just west of Lambasa. They are found within the bay separating the main island from the eastern peninsula[2], but are not known to occur on the peninsula itself. Reefs have very recently been elevated along the southeastern coast

and are found at an elevation of 75 to 100 feet. So recently have these reefs been uplifted that the lagoon flat and outer barrier reef are still preserved intact.

I visited only the eastern and central portions of Vanua Levu. The modern fringing reefs are here developing either along the shore-line of recently submerged volcanic rocks or on coastal flats formed of the fine ash swept from the elevated hills of submarine tuffs. The most recent movements have been differential and while uplift has taken place at the southeastern side of the island, subsidence has occurred to the east and north. The modern barrier reefs occur where subsidence has taken place either due to tilting or faulting during uplift.

3. The Lau Islands.—The Lau Islands lie east of the larger islands of Fiji and are scattered over 300 miles of the ocean floor from the 16th to the 20th parallel of south latitude and from the 178th to the 179th meridian of west longitude. There are from 40 to 50 islands ranging in size from a half a mile to 20 miles in length. The islands may be grouped empirically in three classes.

1. Islands composed of volcanic rocks and limestone.
2. Islands composed of limestone alone.
3. Islands composed of volcanic rocks alone.

The volcanic islands usually have a number of separate peaks rising to altitudes of 600 to 900 feet, whereas the islands composed of limestone rise to nearly a constant level about their edges but are often depressed toward their center.

The limestone is always coraliferous and is raised to a maximum elevation of 1030 feet in the island of Vatu Vara. In every case studied the limestone rests unconformably on a basement of eroded volcanic rocks, indicating subsidence. Certain of the elevated limestones have the atoll or barrier reef form and the inference is drawn, as no unconformities are found within the limestone, that the elevated atolls were formed during the subsidence of the underlying volcanic surface.

The corals included in the elevated limestones are Pleistocene or Recent in age according to the determination of Dr. T. W. Vaughan.

Many of the elevated limestone islands have been greatly reduced in size by atmospheric solution. Occasionally, as in the cases of Fulanga and Ongea, sea-level flats have developed. In most of the islands the flats have been submerged and the residual masses of limestone dotting the flats have formed undercut islets scattered over a lagoon 10 to 15 fathoms in depth. I believe the submergence is due to actual subsidence since it is more recent than the return of the waters to the ocean after the Glacial epoch, and since Pleistocene wave erosion would

have destroyed the fragile undercut islets if the lagoon floors from which they rise were fashioned by this agency.

The islands originated about the middle of the Tertiary period during the extrusion of the lavas of the second andesitic period of Viti Levu. The volcanoes thus formed were maturely eroded and subsided. Four or five hundred feet of coraliferous limestone were deposited unconformably on the subsiding surfaces and were later elevated. A second period of erosion followed and again basaltic volcanoes built cones on the surfaces of the eroded limestone. Within quite recent times the islands have subsided 50 to 90 feet and the modern coral reefs are developing on the eroded and submerged platforms.

4. Summary of the Theoretical Results of the Expedition.—My views concerning the origin of the barrier reefs and atolls of Fiji may be summarized as follows:—

1. The elevated reefs were deposited in all known cases unconformably on eroded surfaces of volcanic rocks. Atolls and barrier reefs were among the forms developed during this period of subsidence.

2. Many atolls and barrier reefs are now developing on platforms of elevated limestone which have been eroded to fairly even surfaces by atmospheric solution and later submerged.

3. Of the several theories concerning the origin of barrier reefs and atolls only Darwin's theory postulates a subsiding surface eroded above sea-level. But this theory is firmly based on the conception of progressive, though intermittent, subsidence of large segments of the earth's crust. If such subsidence is conceived to have begun in the early Tertiary period, the writer is convinced that it characterized the larger part of the Tertiary and Pleistocene periods in which the elevated limestones of Fiji developed. But since the Pleistocene period the algebraic sum of the movements has been positive and uplift has resulted, although the sum, if reckoned from the early Tertiary, is negative and the ultimate result has been subsidence. The present reefs are, however, dependent upon the Pleistocene and Recent movements for their form. Such movements have been progressively upward with only minor periods of subsidence. They are also local in their effect and are dependent undoubtedly on volcanic activity, in part due to the transfer of material from the inner to the outer portions of the earth's crust, and in part to the secular cooling and consolidation of the extruded lavas.[3,4] Hence it cannot be said that the modern reefs of Fiji fully support Darwin's theory.

4. The data assembled by Daly[4] and Vaughan[5] convince the writer that Pleistocene platforms exist very generally throughout the coral seas.

Yet while this is true, the platforms in Fiji are post-Pleistocene in their development. The writer was unable to discover any evidence of Pleistocene wave-cut platforms.

[1] Woolnough, W. G., *Sydney, Proc. Linn. Soc. N. S. Wales,* **32,** 1907 (431–474).

[2] Guppy, H. B., *Observations of a Naturalist in the Pacific,* vol. 1, Macmillan, 1903.

[3] Gerland, G., *Beitr. Geophys., Leipzig,* **2,** 1895, (56).

[4] Daly, R. A., *Boston, Proc. Am. Acad. Arts Sci.,* **51,** 1915, (157–251), p. 232.

[5] Vaughan, T. W., *Washington, J. Acad. Sci.,* **6,** 1916, (53–66).

DOMINANCE OF LINKED FACTORS AS A MEANS OF ACCOUNTING FOR HETEROSIS

By Donald F. Jones

BUSSEY INSTITUTION, HARVARD UNIVERSITY[1]

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The increase of growth derived from crossing in both animals and plants, which has been called heterosis, and the converse fact of decreased vigor resulting from inbreeding have been known for a long time but have never been satisfactorily accounted for.

The investigations of East,[2] G. H. Shull[3] and Hayes[4] show that inbreeding does not result in a continuous degeneration but that the effects of inbreeding gradually become less as complete homozygosis is approached and for all practical purposes finally become constant. Unlike strains are isolated which differ in the amount of growth they produce. In many species these homozygous strains are always less vigorous than either parent. The decrease in vigor due to inbreeding has been shown to be correlated approximately with the decrease in the number of heterozygous factors present but without showing why there should be such a relation. It was simply stated that "greater developmental energy is evolved when the mate to an allelomorphic pair is lacking than when both are present in the zygote."[4]

The conception of dominance as proposed by Keeble and Pellew[5] as a means of accounting for these facts has had two serious objections. If heterosis were due to dominance of characters it was thought possible to recombine in generations subsequent to the F_2 all of the dominant characters in some individuals and all the recessive characters in others in a homozygous condition. Such homozygous individuals could not be changed by inbreeding. Moreover, if dominance were concerned it was considered that the F_2 would have an asymmetrical distribution.

Both of the above objections to dominance have failed to take into consideration the facts of linkage. If the factors which govern an organism's development are distributed in all the chromosomes and passed